Proton Plan
MI Radiation Issues and Collimation
Directors Review
August 2005

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MI Radiation Issues and Collimation

Topics to Be Discussed:

- MI Radiation Levels and Trends
- MI Radiation Monitoring Program
  - Residual Radiation and Monitoring Automation
  - Loss Monitor Status and Upgrades
- MI Collimation Prospects and Plans
  - Loss Issues
  - Lattice Overview
  - Loss Study and Simulation Plans
- MI8 Collimation
  - Specification
  - Design and Implementation Plans
- Risk Assessment, Schedule, Costs

MI Radiation Issues and Collimation

- The Main Injector was sited at a depth which provides adequate shielding so **environmental issues do not normally arise**.
  - Exception: MI Abort is authorized for limited use.
- However, all components are designed for hands-on maintenance. **Residual radiation must be kept to levels which permit maintenance**.
  - We interpret this to mean less than 100 mr at 1 foot.
  - Unlike the Booster RF, there are no MI components (rf, instrumentation) which are predicted to need maintenance and have radiation-inducing aperture limitations. **Where will residual radiation define limits?**
- Radiation damage to components may be a separate issue. We expect to operate the machine such that the residual radiation will be limiting. [Do not dump beam in magnets!]

MI Radiation Issues and Collimation

Tunnel Residual Radiation Monitoring:

- **Diagnostic Measurements** – all sides of beam pipe at locations which show significant radiation
  - Carried out in June-August 2004 and as possible in 2005
  - Few mr exposure per survey in 2004, 20-30 mr in 2005
  - 2005 surveys incomplete (limited by time and exposure)
  - Comparison of top *vs.* bottom or inside *vs.* outside diagnostic of machine problems
- **Monitoring** – periodic measurements at 'significant' locations around MI Ring.
  - Manually with LSM through July 2005
  - **Bar codes installed, logging meter purchased to monitor about 125 points**
  - Database and data transfer efforts still needed

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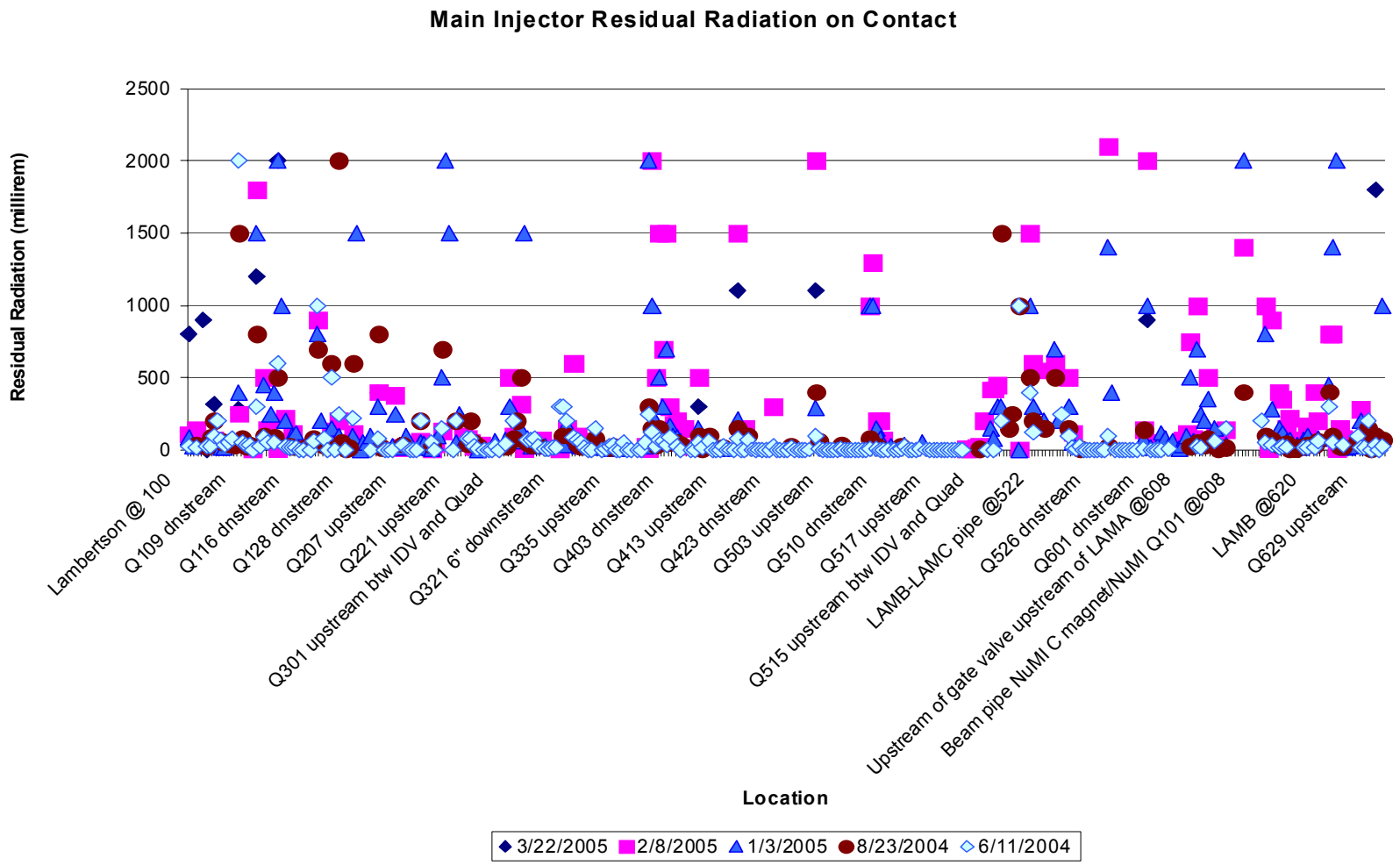
Residual Radiation measurement have been recorded and reviewed.



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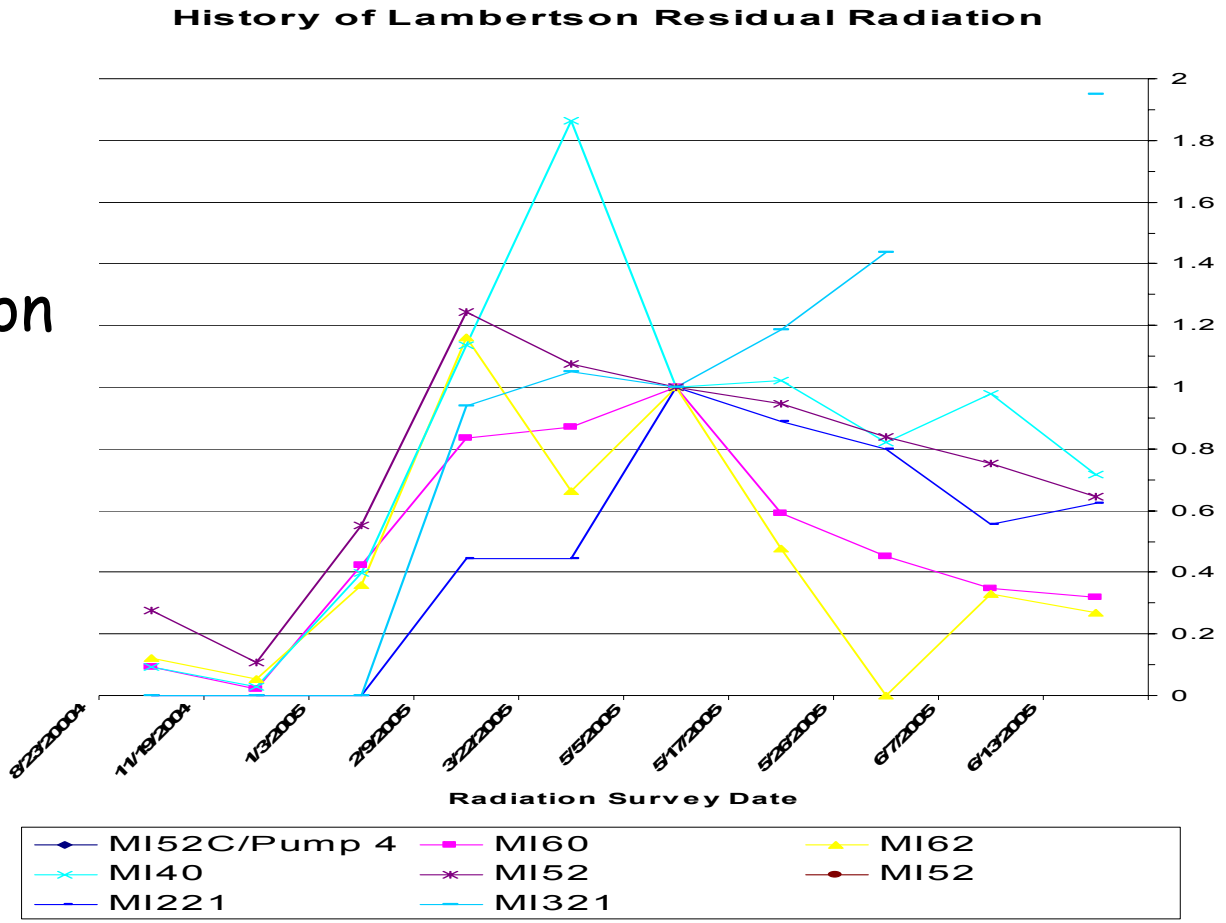
Radiation trends have been monitored at locations with significant radiation

Residual Radiation At Lambertson Locations

Averages Normalized to May 5, 2005 Survey



MI Radiation Issues and Collimation

We must limit the number of hot locations if we hope to understand existing or new loss sources.

Issues noted:

- Vertical problem at D-Quad Minitubes (tails)
- Radial Problem at F-Quad downstream (longitudinal)
- Lambertsons
- Blunders (alignment, BPM errors)

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MI Loss Monitors

- Adequate number of Tevatron-style Loss Monitors
- Old Electronics is not adequate
  - Cannot report integrated losses but from a few locations. It is adequate for many studies but not suitable for most long term monitoring needs.
- New electronics is being developed (Run II) which will provide much better real time and logging capability. It should be available in FY06.

Expect to predict residual radiation based on losses (As in Booster). If some losses are not seen by existing LM's we can supplement them with coaxial 'Total Loss Monitors' for some areas.

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What do we know about Main Injector Losses?

- Losses at Injection
- 8 GeV Lifetime
- Slip-stacking Losses – beam lost from design buckets (currently our most serious problem)
  - Recaptured in undesired buckets (lost at inj or ext)
  - Uncaptured beam (DC Beam lost on acceleration)
- Losses at MI Transition
- Losses during extraction/transfer

Each of these loss sources has a distinctive pattern for creating residual radiation

MI Radiation Issues and Collimation

The Main Injector Lattice has no collimation locations in the design. Features include:

- Regular Cells
  - Only Mini-straight sections
  - Moderate dispersion
- Dispersion suppressor cells
  - No straight section space
- Straight section cells
  - Design dispersion is zero
  - All have dedicated use – transfer, instrumentation, rf

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MI Collimation Possibilities

Straight section uses:

- MI52, MI62 Transfer to Tevatron - radial
- MI40 Abort – radial
- MI 10 Injection – vertical plus instrumentation
- MI60 RF, Instr, NuMI Transfer – radial
- MI22, MI32 Radial Transfer to RR
- MI30 Mostly used for electron cooling

Currently we are considering creating some vertical collimation at MI22 or MI32 and radial at MI30

No location with dispersion has been identified.

Proposed lattice change – Beams-doc-1930

Un-suppresses dispersion into MI300 Straight

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MI Loss and Collimation Study

Nikolai Mokhov and colleagues will carry out a study of apertures and loss mechanisms in the Main Injector with the goal of prescribing a suitable set of collimators to localize beam lost do to various identified mechanisms

We speculate that significant lattice modifications will be required to create a section with dispersion where collimation can be placed if we wish to remove unaccelerated beam with collimation.

MI Radiation Issues and Collimation

MI8 Collimation Plan

Purpose:

To remove >0.1% of Booster beam in transverse tails which would be lost in Main Injector. This should reduce somewhat the radiation levels in hot spots and the Main Injector and should greatly reduce the number of hot spot, permitting other radiation-inducing problems to be identified and controlled.

Specification:

Massive collimators designed for up to 2% of Booster beam lost without excessive residual radiation. Precision motion control outside of collimators.

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MI8 Beam Halo:

Even without beam tails in Booster, the field quality of the MP02 Pulsed Extraction Septum may create beam halos (Beams-doc-1573, M-J.Yang)

Scraping in MI8 can remove such halo effectively.

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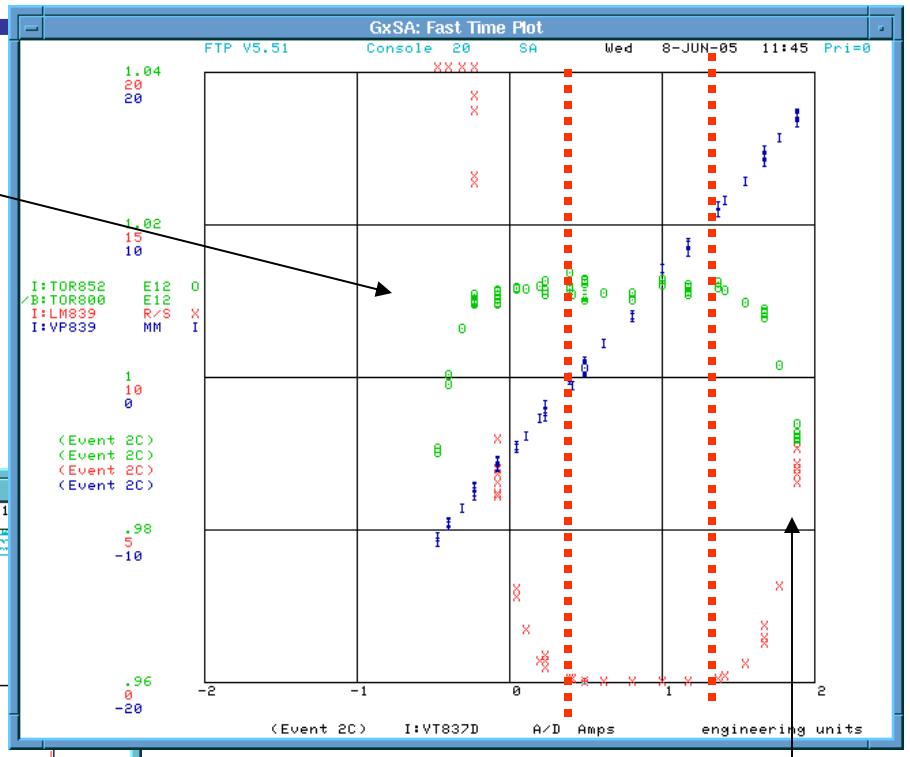
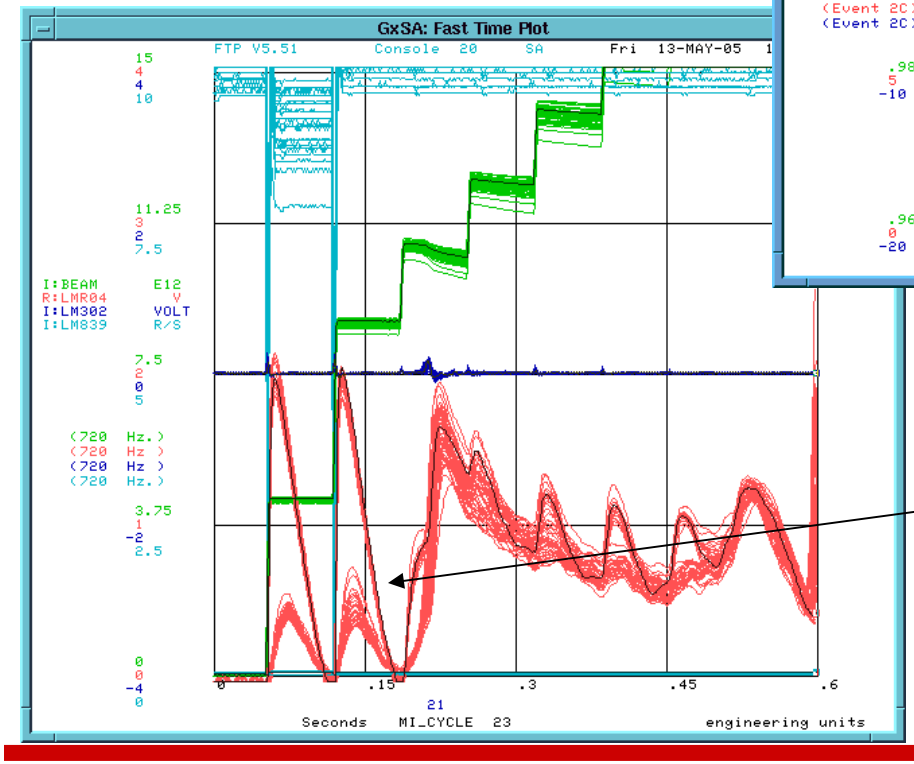
Asymmetric beam distribution at 839 (MI8 Line) (Proposed collimator location)



Loss Monitor at ECool



Aperture scan at Location 839

Scraping level at 839 ~2%

Reduces losses at LMR04

Vertical phase advance from MP02 to 839 is 4.9 x 2π

MI Radiation Issues and Collimation

In each region will insert:

- Vertical BPM
- 45" long collimator
- Bellows
- 45" long collimator
- Loss Monitor
- Fixed mask

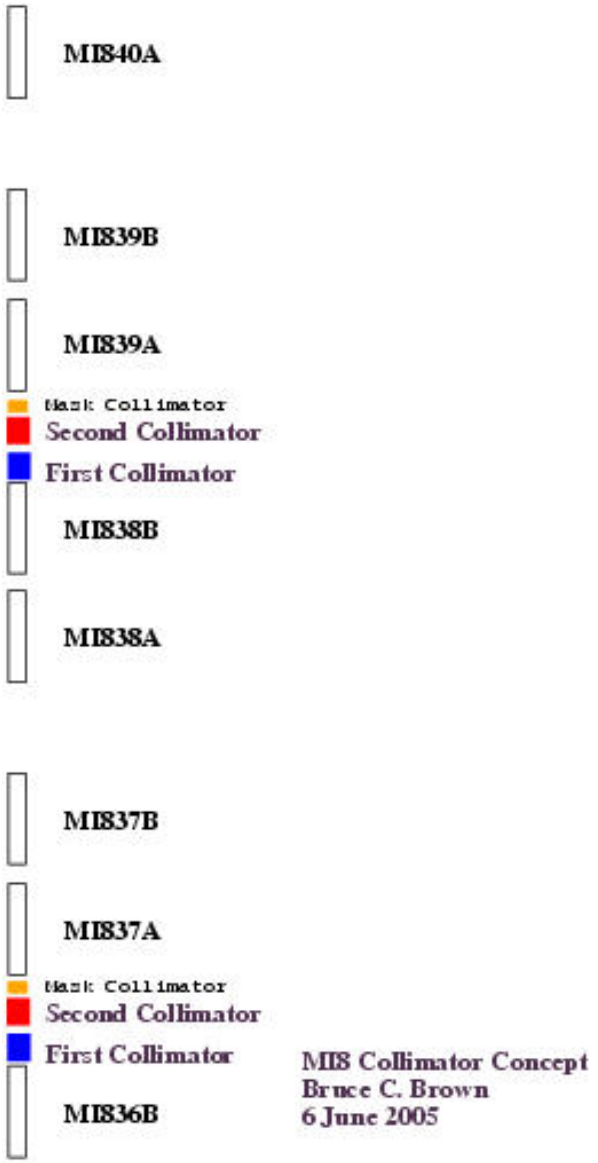
Each collimator has

2" x 2" vacuum hole

3.5" x 3.5" Stainless vacuum pipe

20" x 20" x 35" Steel absorber

30" x 30" x 45" Marble shield

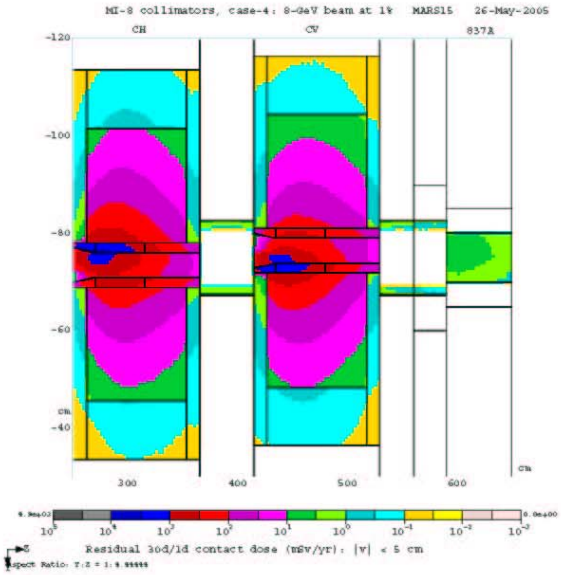


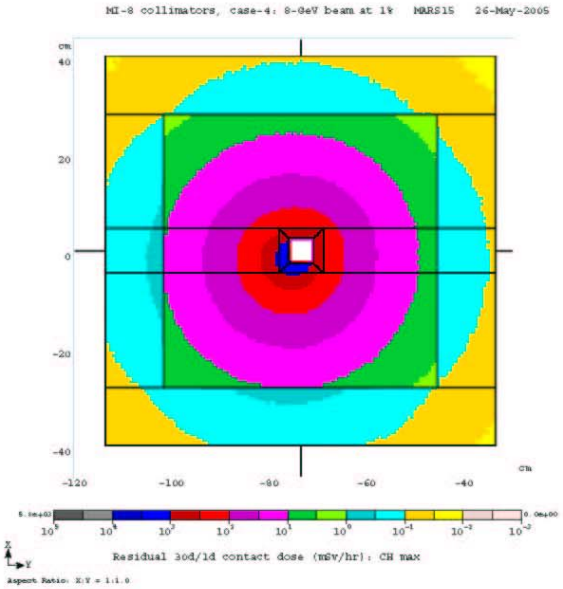
MI Radiation Issues and Collimation

Design based on MARS calculations by N. Mokhov

Shielding Assessment To be done With new complete Simulations No Problems Anticipated

RESIDUAL DOSE IN IRON-MARBLE COLLIMATORS





Fermilab

N. Mokhov

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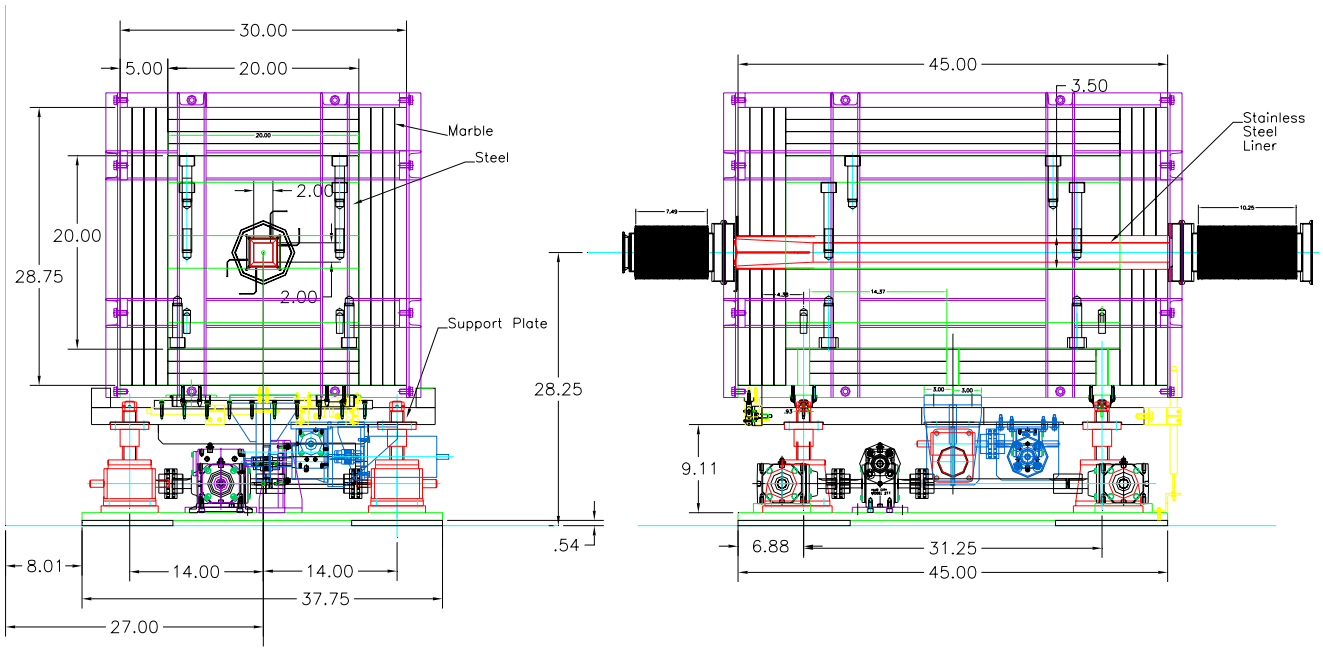
Mechanical Design for One Collimator

- Motion control for horizontal and vertical motion



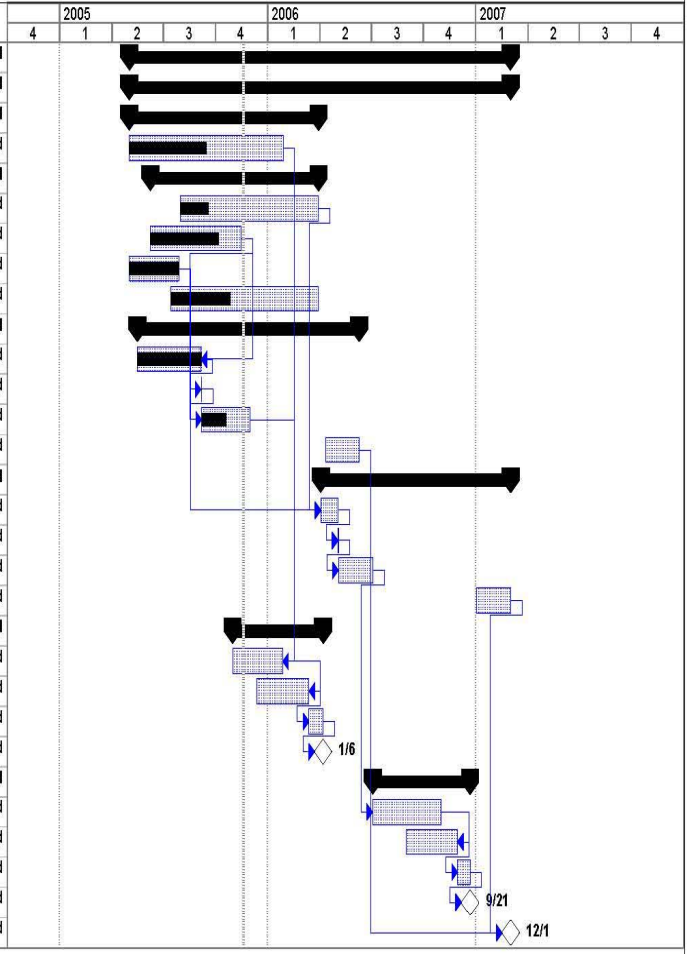
Mechanical Concepts based on Booster Collimator System

MI Radiation Issues and Collimation

8/19/05

Proton Plan
Collimation Systems
Schedule Information

Uniq	WBS	Name	St	Fin	%	Float
20	**1.3.2**	**Collimation Systems**	**2/1/05**	**12/1/06**	**35%**	**80 d**
218	**1.3.2.1**	**Collimation Systems Design**	**2/1/05**	**12/1/06**	**46%**	**80 d**
107	**1.3.2.1.1**	**MI Loss Studies**	**2/1/05**	**12/29/05**	**49%**	**151 d**
113	1.3.2.1.1.1	MI Loss Studies: Beam	2/1/05	10/28/05	50%	47 d
110	**1.3.2.1.1.2**	**MI Loss Studies: Simulation**	**3/10/05**	**12/29/05**	**42%**	**7 d**
115	1.3.2.1.1.2.1	MI Loss Study: Simulation	5/2/05	12/29/05	20%	7 d
131	1.3.2.1.1.2.2	MI-8 Loss Study: Simulation	3/10/05	8/15/05	75%	0 d
109	1.3.2.1.1.3	Exploratory Residual Radiation Measurements	2/1/05	4/28/05	100%	0 d
134	1.3.2.1.1.4	Systematic Residual Radiation Measurements	4/15/05	12/29/05	40%	151 d
111	**1.3.2.1.2**	**MI-8 Collimation System Design & Commission**	**2/15/05**	**3/10/06**	**60%**	**265 d**
117	1.3.2.1.2.1	Develop Concept for MI-8 Collimation System	2/15/05	6/6/05	100%	0 d
118	1.3.2.1.2.2	Review Concept for MI-8 Collimation System	6/7/05	6/7/05	100%	0 d
119	1.3.2.1.2.3	Design MI-8 Collimation System	6/8/05	8/31/05	50%	3 d
133	1.3.2.1.2.4	MI-8 Collimation System Commissioning	1/11/06	3/10/06	0%	265 d
112	**1.3.2.1.3**	**MI Collimation System Design & Commission**	**1/3/06**	**12/1/06**	**0%**	**7 d**
121	1.3.2.1.3.1	Develop Concept for MI Collimation System	1/3/06	2/1/06	0%	7 d
122	1.3.2.1.3.2	Review Concept for MI Collimation System	2/2/06	2/2/06	0%	7 d
123	1.3.2.1.3.3	Design MI Collimation System	2/3/06	4/3/06	0%	7 d
127	1.3.2.1.3.4	MI Collimation System Commissioning	10/3/06	12/1/06	0%	80 d
341	**1.3.2.2**	**MI-8 Collimation Syst Procure/Fab/Install**	**8/1/05**	**1/6/06**	**0%**	**3 d**
252	1.3.2.2.1	Procure MI-8 Collimation System	8/1/05	10/27/05	0%	3 d
251	1.3.2.2.2	Fabricate MI-8 Collimation System	9/13/05	12/12/05	0%	3 d
120	1.3.2.2.3	Install MI-8 Collimators	12/13/05	1/6/06	0%	3 d
326	1.3.2.2.4	MI-8 Collimators Installation Complete	1/6/06	1/6/06	0%	3 d
338	**1.3.2.3**	**MI Collimation Syst Procure/Fab/Install**	**4/4/06**	**9/21/06**	**0%**	**7 d**
253	1.3.2.3.1	Procure MI Collimation System	4/4/06	8/1/06	0%	7 d
124	1.3.2.3.2	Fabricate MI Collimation System (Future Parent)	6/2/06	8/30/06	0%	7 d
125	1.3.2.3.3	Install/Align MI Collimation System	8/31/06	9/21/06	0%	7 d
327	1.3.2.3.4	MI Collimation System Install/Align Complete	9/21/06	9/21/06	0%	7 d
126	1.3.2.4	Main Injector Loss Mitigation Complete	12/1/06	12/1/06	0%	80 d



MI Radiation Issues and Collimation

WBS	Name	Esc SWF	Esc M&S	Cont %
1.3.2	**Collimation Systems**	**$376,015**	**$634,695**	**86%**
1.3.2.1	**Collimation Systems Design**	**$149,997**	**$4,241**	**68%**
1.3.2.1.1	**MI Loss Studies**	**$59,582**	**$4,241**	**54%**
1.3.2.1.1.1	MI Loss Studies: Beam	$8,522	$0	**60%**
1.3.2.1.1.2	**MI Loss Studies: Simulation**	**$26,200**	**$0**	**51%**
1.3.2.1.1.2.1	MI Loss Study: Simulation	$20,590	$0	**60%**
1.3.2.1.1.2.2	MI-8 Loss Study: Simulation	$5,610	$0	**20%**
1.3.2.1.1.3	Exploratory Residual Radiation Measurements	$2,633	$0	**0%**
1.3.2.1.1.4	Systematic Residual Radiation Measurements	$22,228	$4,241	**60%**
1.3.2.1.2	**MI-8 Collimation System Design & Commission**	**$35,114**	**$0**	**45%**
1.3.2.1.2.1	Develop Concept for MI-8 Collimation System	$8,999	$0	**0%**
1.3.2.1.2.2	Review Concept for MI-8 Collimation System	$0	$0	**0%**
1.3.2.1.2.3	Design MI-8 Collimation System	$20,622	$0	**60%**
1.3.2.1.2.4	MI-8 Collimation System Commissioning	$5,492	$0	**60%**
1.3.2.1.3	**MI Collimation System Design & Commission**	**$55,301**	**$0**	**100%**
1.3.2.1.3.1	Develop Concept for MI Collimation System	$12,971	$0	**100%**
1.3.2.1.3.2	Review Concept for MI Collimation System	$0	$0	**0%**
1.3.2.1.3.3	Design MI Collimation System	$30,962	$0	**100%**
1.3.2.1.3.4	MI Collimation System Commissioning	$11,368	$0	**100%**
1.3.2.2	**MI-8 Collimation Syst Procure/Fab/Install**	**$29,800**	**$208,974**	**60%**
1.3.2.2.1	Procure MI-8 Collimation System	$1,691	$206,404	**60%**
1.3.2.2.2	Fabricate MI-8 Collimation System	$19,041	$0	**60%**
1.3.2.2.3	Install MI-8 Collimators	$9,068	$2,570	**60%**
1.3.2.2.4	MI-8 Collimators Installation Complete	$0	$0	**0%**
1.3.2.3	**MI Collimation Syst Procure/Fab/Install**	**$196,218**	**$421,480**	**100%**
1.3.2.3.1	Procure MI Collimation System	$146,214	$411,200	**100%**
1.3.2.3.2	Fabricate MI Collimation System (Future Parent)	$31,867	$0	**100%**
1.3.2.3.3	Install/Align MI Collimation System	$18,136	$10,280	**100%**
1.3.2.3.4	MI Collimation System Install/Align Complete	$0	$0	**0%**
1.3.2.4	Main Injector Loss Mitigation Complete	$0	$0	**0%**

Risk and Risk Mitigation Issues

Orbit Control not Adequate	Set for wider aperture (less collimation) until have auto tune or better power supplies
Schedule	Most motion control items have arrived. Drafting began 15 August.
Assembly Manpower	Try to get design/fabrication in time to avoid manpower crunch.

MI Radiation Issues and Collimation

Summary:

- Main Injector losses have grown – will continue to grow even with improved Booster Beam – we must control residual radiation produced by these losses.
- Plan is being implemented to provide bar-code labeled monitoring location and logging meter to allow monitoring of residual radiation with manageable personnel exposure.
- Improved loss monitor electronics available in 2006 will help maintain adequate knowledge of losses
- Program to measure, simulate and understand Main Injector losses is beginning soon. Expect to design MI collimator system and suitable lattice modifications.

MI Radiation Issues and Collimation

Summary (continued):

Losses currently due to tails of injected Booster beam will create non-trivial residual radiation at proposed operating intensities.

Collimation in the MI8 Line to remove beam tails is specified and design/fabrication is underway.

Cost, schedule and manpower needs are manageable but will continue to require commitment to permit installation and commissioning in FY06.